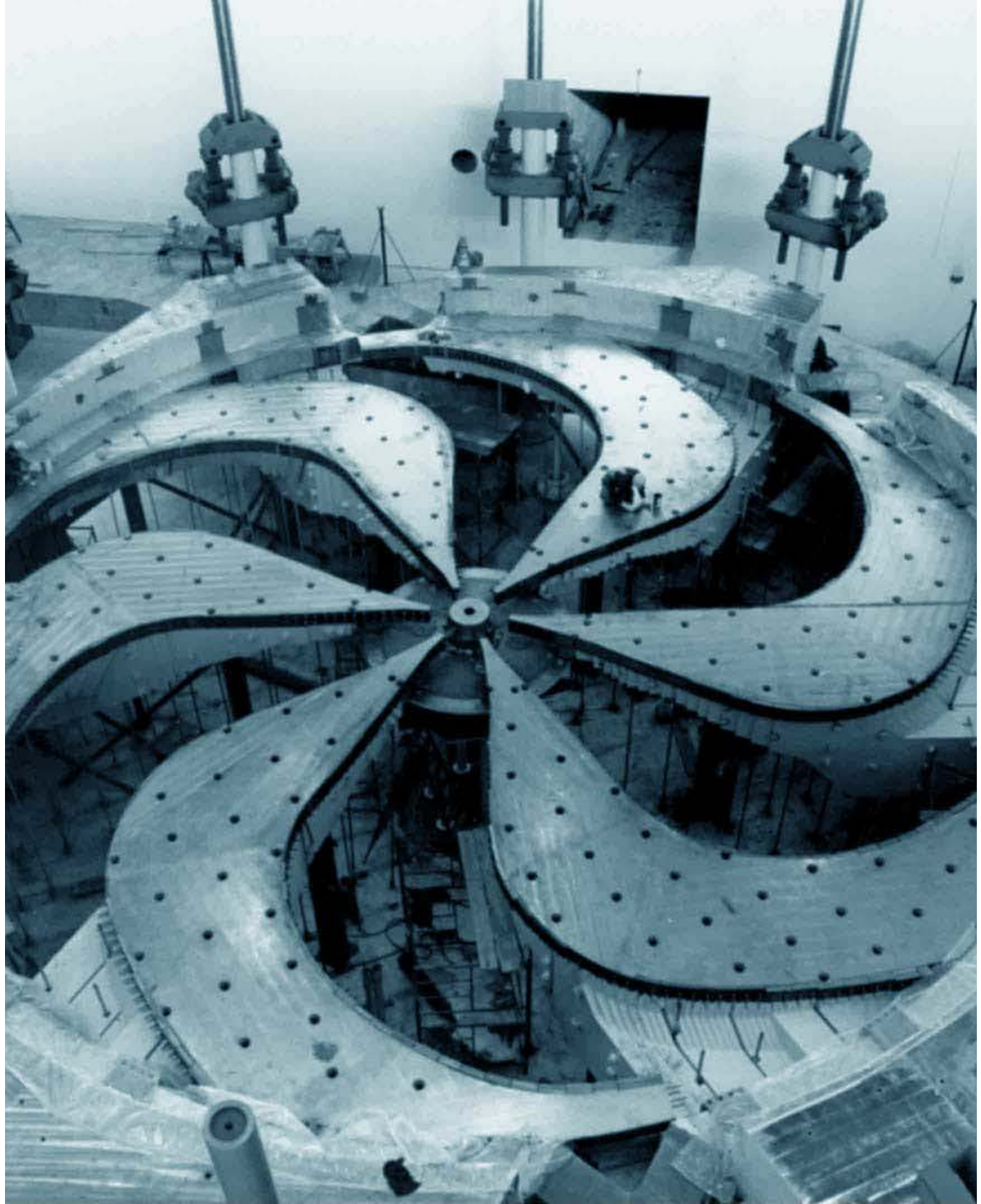
Production of medical radionuclides at TRIUMF



Valery Radchenko, PhD
TRIUMF/UBC

July 31st, 2023

Life Sciences Division

Applied Ion Beams

Cornelia Hoehr

Monika Stachura

Nuclear Chemistry

Valery Radchenko

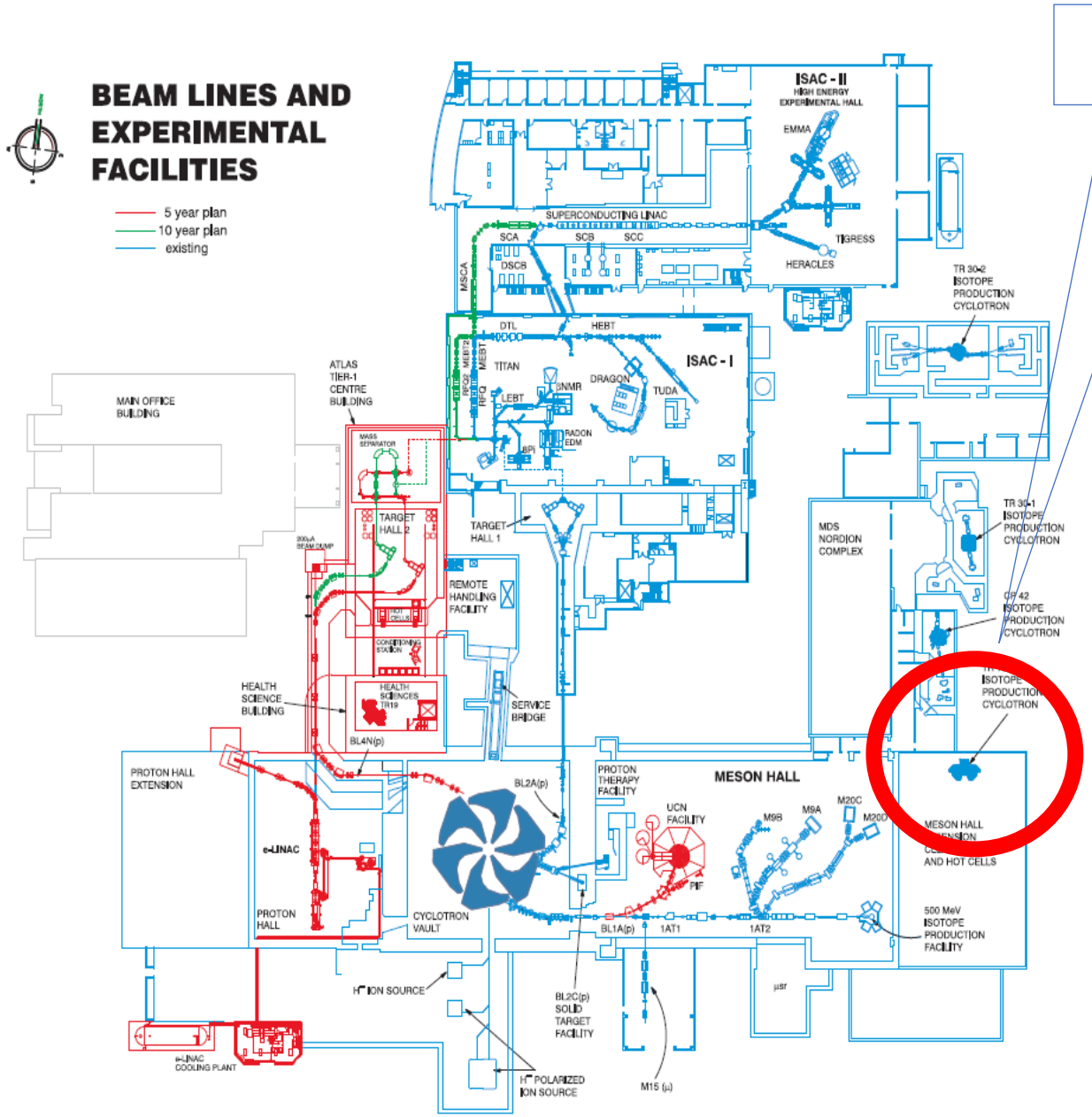
Paul Schaffer

Applied Isotopes

Hua Yang

Caterina Ramogida

Production of medical radionuclides at TRIUMF:TR-13



TR-13

ISAC
Production of pre-clinical quantitates of imaging and therapeutic radionuclides

Isotope Production Facility (IPF), BL1A

ARIEL
Collection chamber
Proton and electron beamlines

IAMI
TR-24

TR-13: work horse of Life Sciences

(p,n)

TR-13 Operation team:

David Prevost
Toni Epp
Spencer Staiger
Ryley Morgan

Routine production of **^{18}F** and **^{11}C** for clinical collaboration partners (UBC hospital, etc.)

Production of diagnostic radionuclides:

Liquid targets:

^{68}Ga, ^{44}Sc, ^{86}Y, ^{89}Zr…….

Easy to handle/transport

Usually, lower yield compared to solid targets

Solid targets:

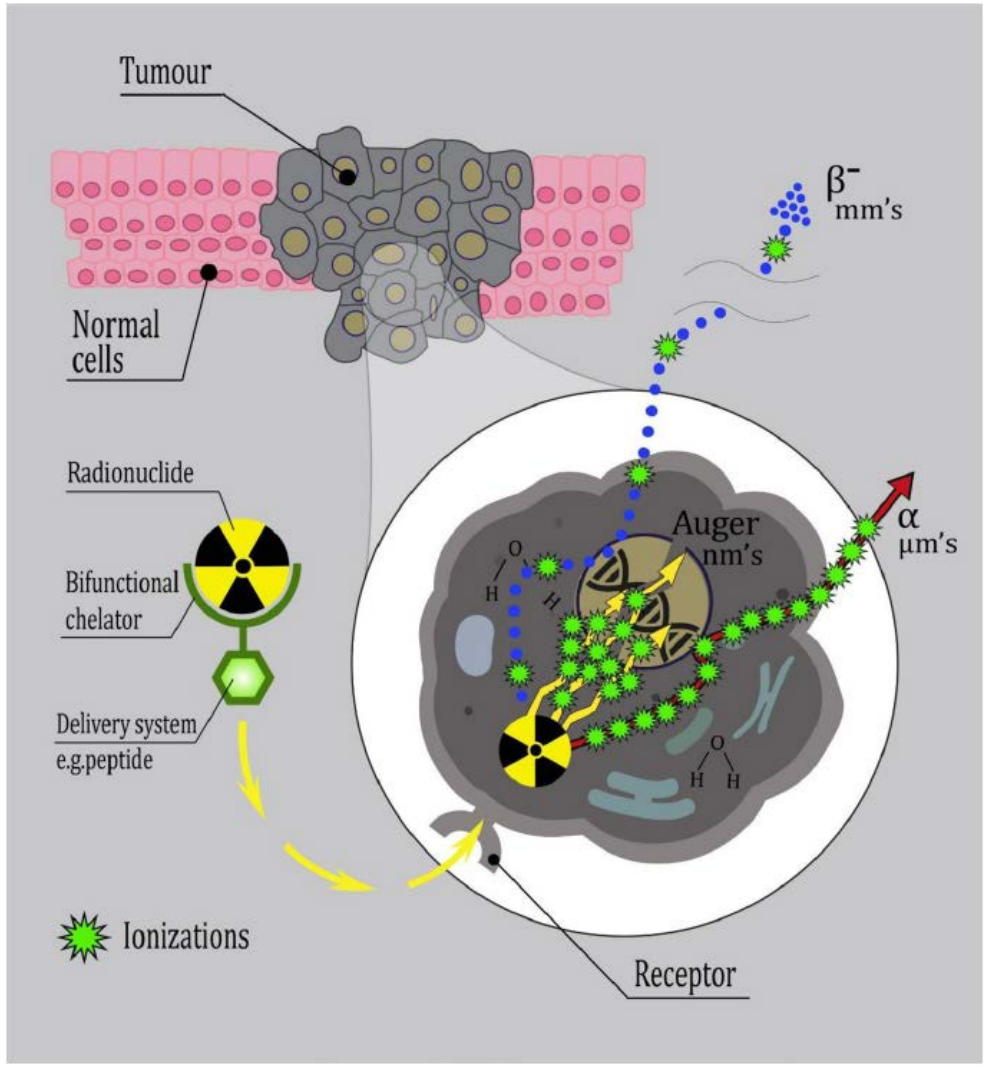
^{68}Ga, ^{44}Sc, ^{45}Ti, ^{64}Cu, ^{86}Y, ^{90}Nb, ^{89}Zr, ^{155}Tb,……

Production of therapeutic radionuclides:

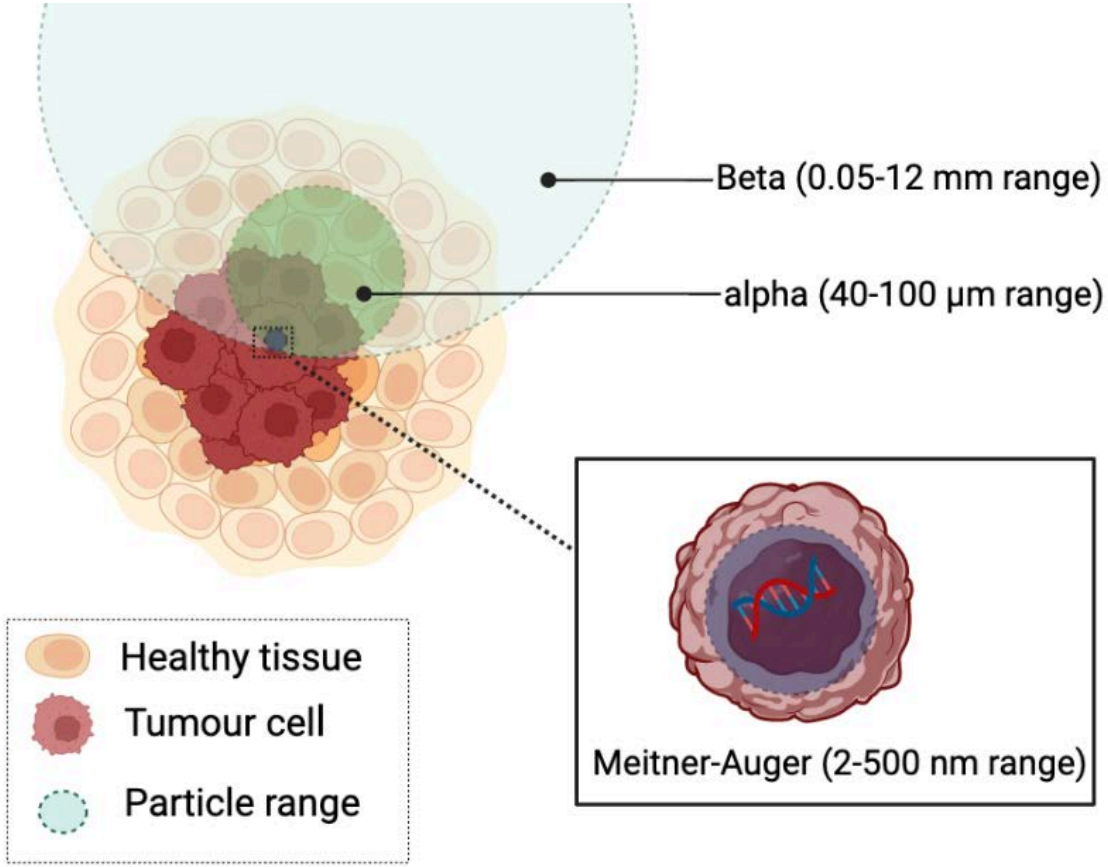
$^{197m+g}$Hg, ^{119}Sb, ^{103}Pd, ^{135}La and ^{165}Er

Targeted Radiation Therapy (TRT): Meitner-Auger Emitters

Radiopharmaceutical design



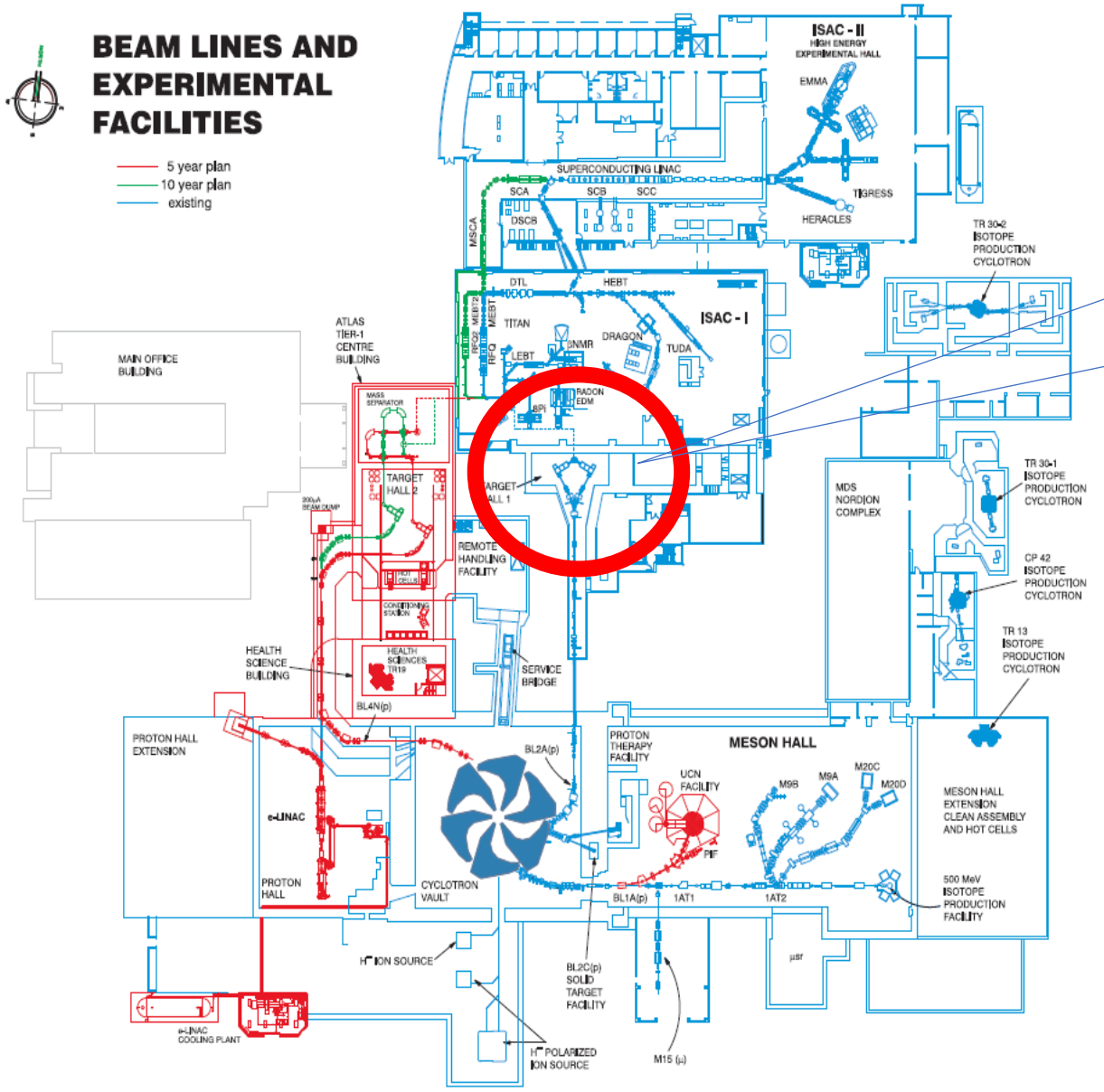
Beta vs. Alpha vs. Auger Emitters



V. Radchenko and C. Hoehr, Nucl. Phys. News, 2020

Filosofov D, Kurakina E, Radchenko V. Nucl. Med. Biol. 2021

Production of medical radionuclides at TRIUMF:ISAC



TR-13

ISAC
Production of pre-clinical quantitates of imaging and therapeutic radionuclides

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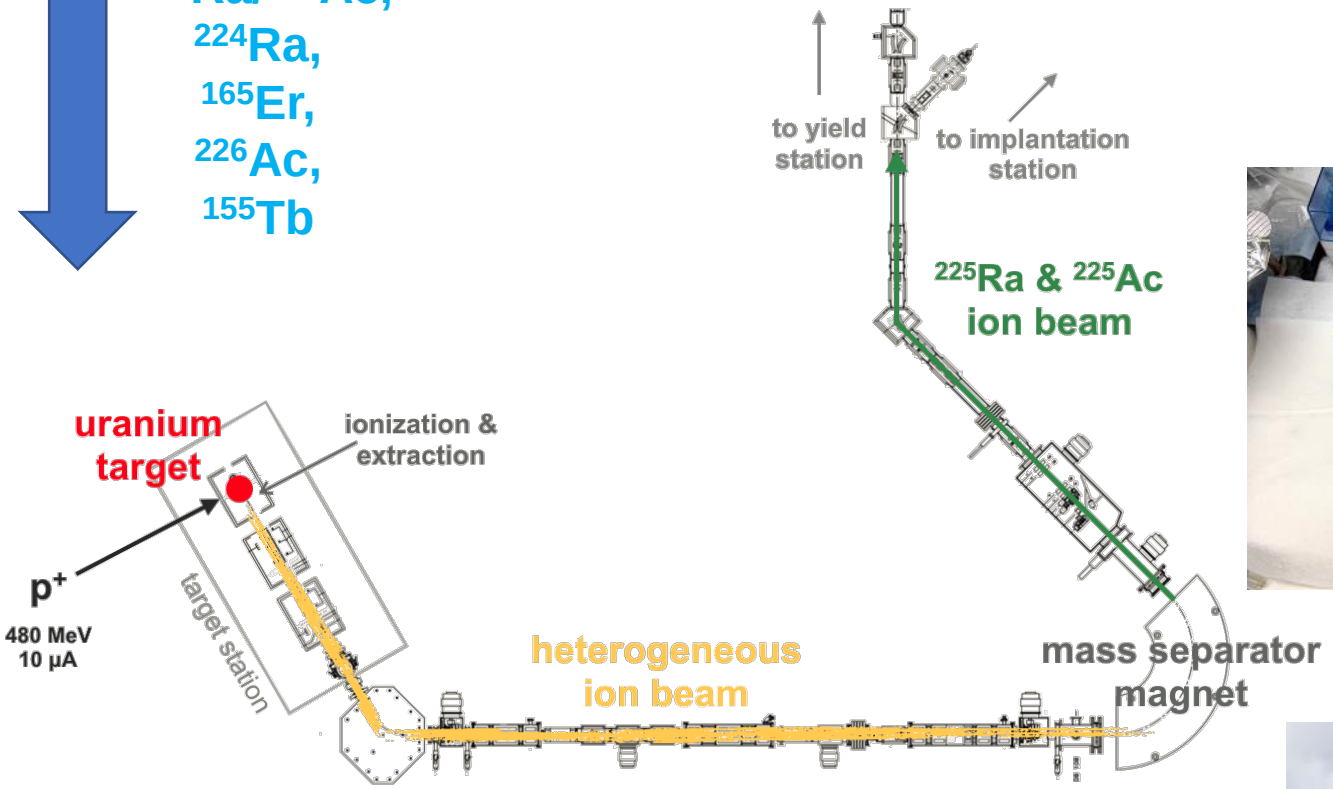
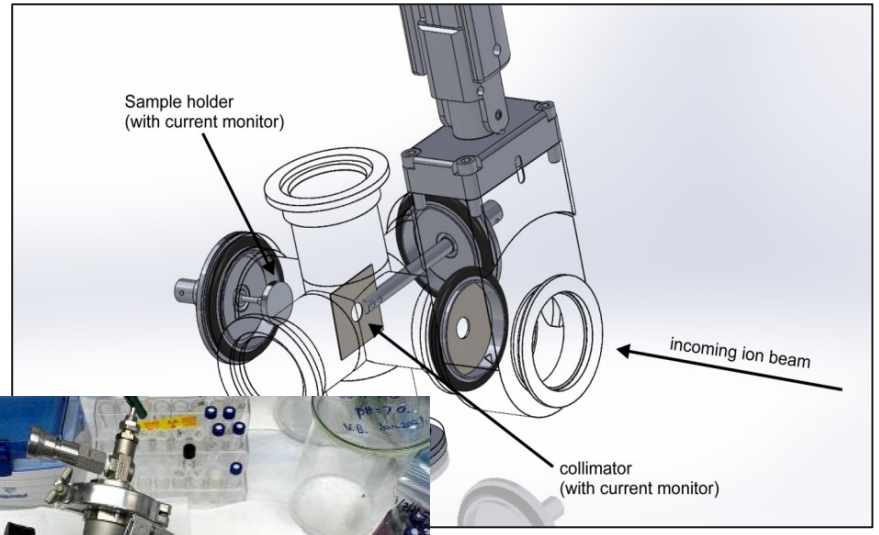
Isotope Separation On-Line

$^{211/209}$At,
^{225}Ra/^{225}Ac,
^{224}Ra,
^{165}Er,
^{226}Ac,
^{155}Tb



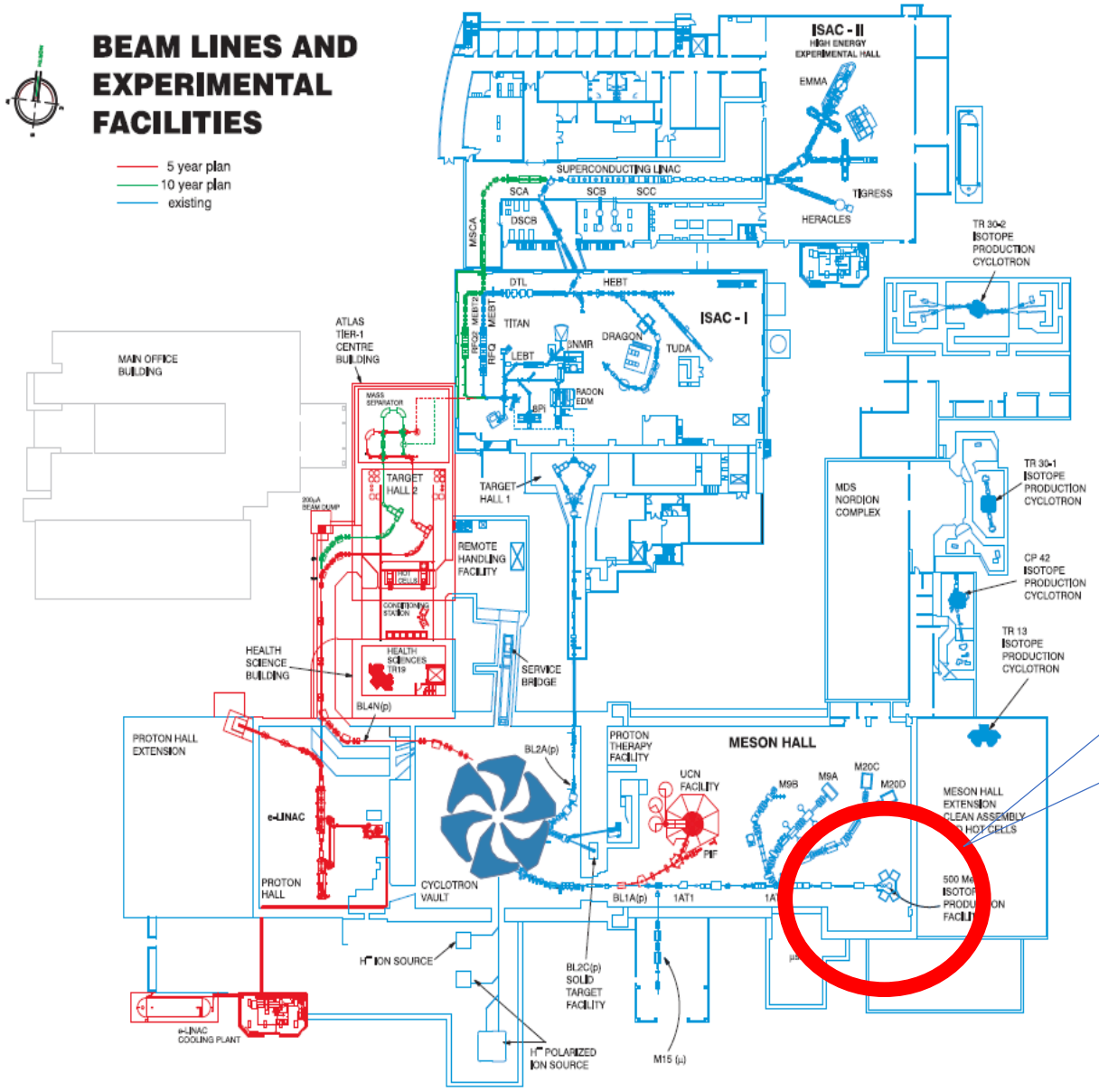


ISAC collection chamber

Peter Kunz

Fiaccabrino, et al. *Nucl Med Biol*. 2021; 94-95:81-91.

Production of medical radionuclides at TRIUMF:BL1A



TR-13

ISAC

Isotope Production Facility (IPF), BL1A

Large scale production of therapeutic radionuclides

ARIEL

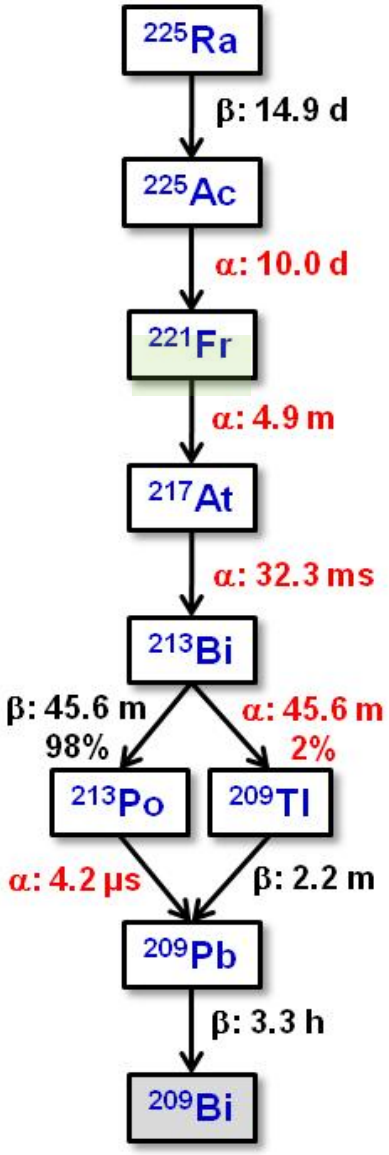
Collection chamber

Proton and electron beamlines

IAMI

TR-24

$^{225}Ac/^{213}Bi$ promising system for Targeted Alpha Therapy (TAT)



- ^{225}Ac ($t_{1/2}$ 9.92 d) in combination with specific biomolecules (e.g. peptides) is a promising system for Targeted Alpha Therapy (TAT)

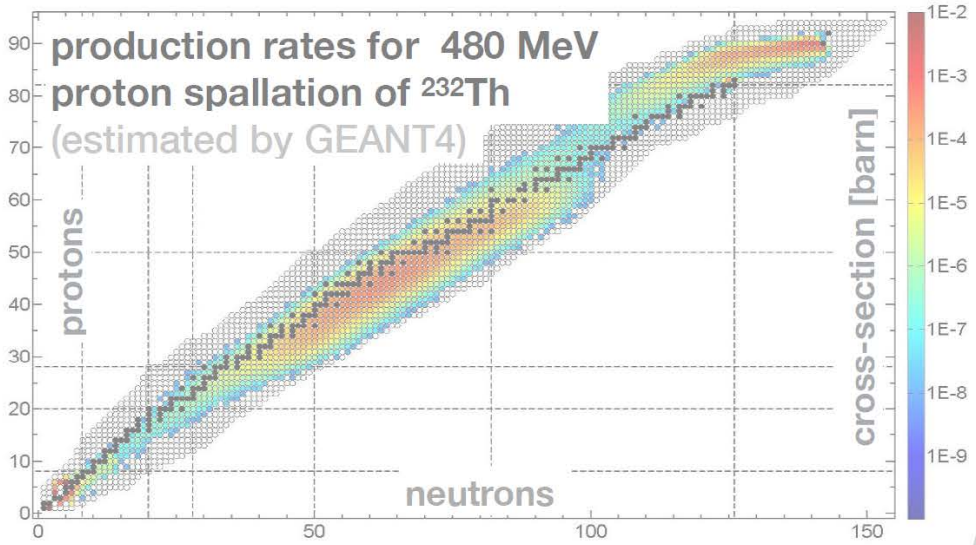
- $^{225}Ac/^{213}Bi$ ($t_{1/2}$ 45.59 min) generator system provides accelerator independent source of ^{213}Bi for medical applications

- Supply is limited/challenging for clinical translation

*International Atomic Energy Agency. Technical Meeting Report "Alpha Emitting Radionuclides and Radiopharmaceuticals for Therapy" IAEA Headquarters Vienna, Austria. 24-28 June **2013***

http://www.nndc.bnl.gov/chart/

High-purity ^{225}Ac production available via ^{225}Ra



^{227}Ra + ^{225}Ra + ^{228}Ra + ^{224}Ra + ^{226}Ra

$t_{1/2}$ = 42 min | $t_{1/2}$ = 14.9 d | $t_{1/2}$ = 5.8 y | $t_{1/2}$ = 3.6 d | $t_{1/2}$ = 1600 y

rapid decay

^{224}Rn ^{222}Rn

Paul Schaffer

^{225}Ac + ^{224}Ac + ^{226}Ac + ^{227}Ac

$t_{1/2}$ = 9.9 d | $t_{1/2}$ = 3 h | $t_{1/2}$ = 29 h | $t_{1/2}$ = 22 y

concerns (from some) about ^{227}Ac content and impact on waste management — no consensus

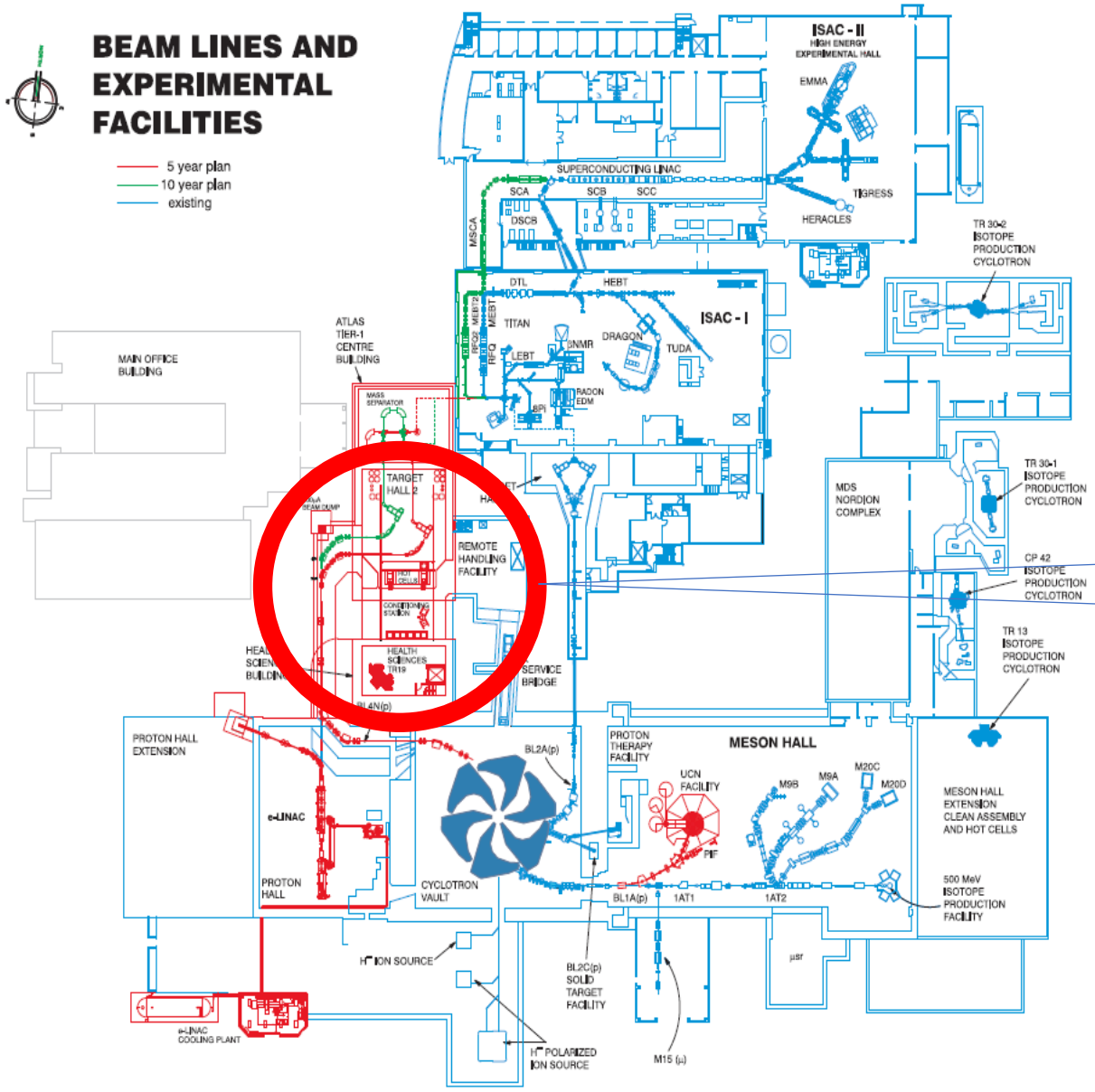
"directly-produced ^{227,225}Ac†"

^{225}Ac + ^{228}Ac

$t_{1/2}$ = 9.9 d | $t_{1/2}$ = 6 h

"generator-produced ^{225}Ac*"

Production of medical radionuclides at TRIUMF: ARIEL



TR-13

ISAC

Isotope Production Facility (IPF), BL1A

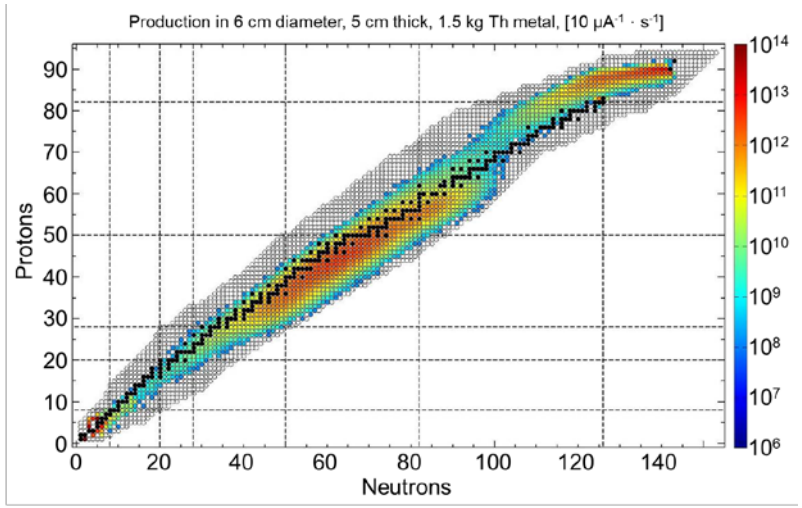
ARIEL
Proton and electron beamlines

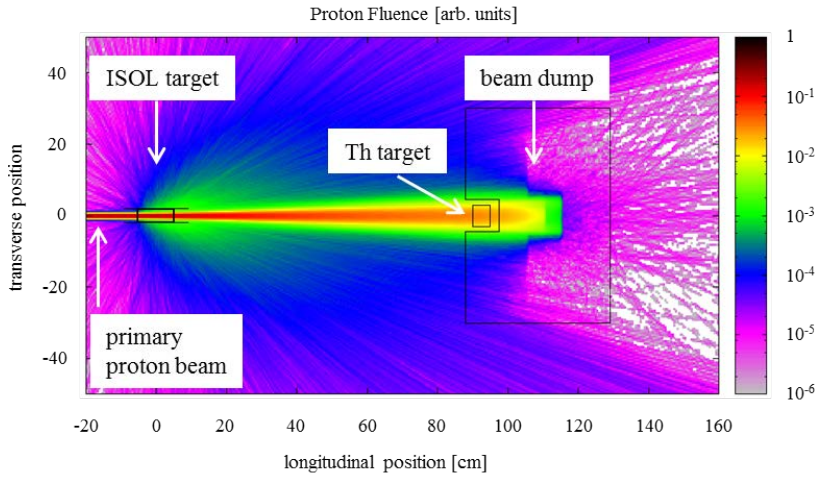
IAMI

TR-24

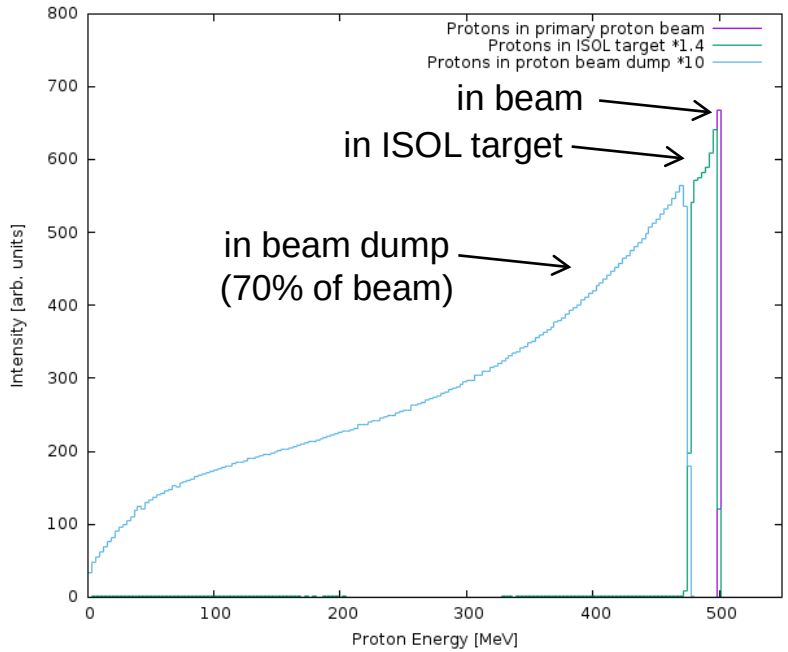
Proton-induced ^{225}Ac production at ARIEL: proton beamline

- Hundreds of co-produced isotopes including, ^{225}Ac, ^{224}Ra, ^{223}Ra, ^{213}Bi, ^{212}Pb, ^{212}Bi

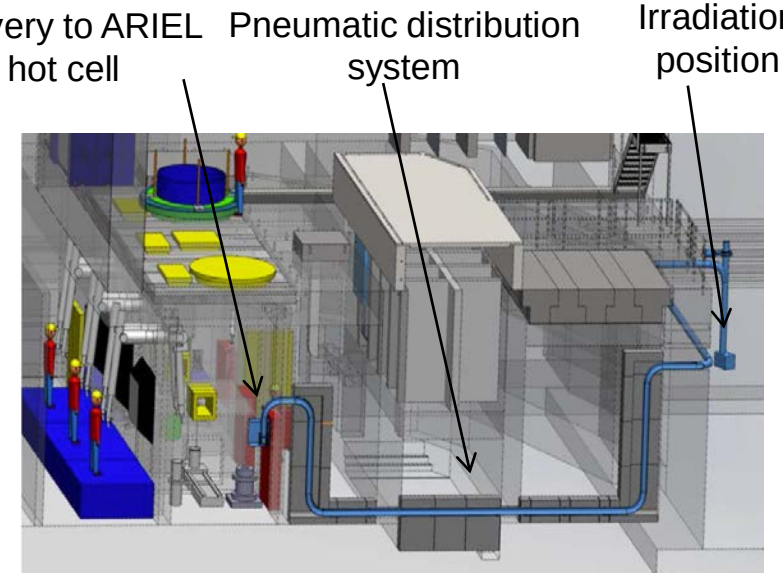


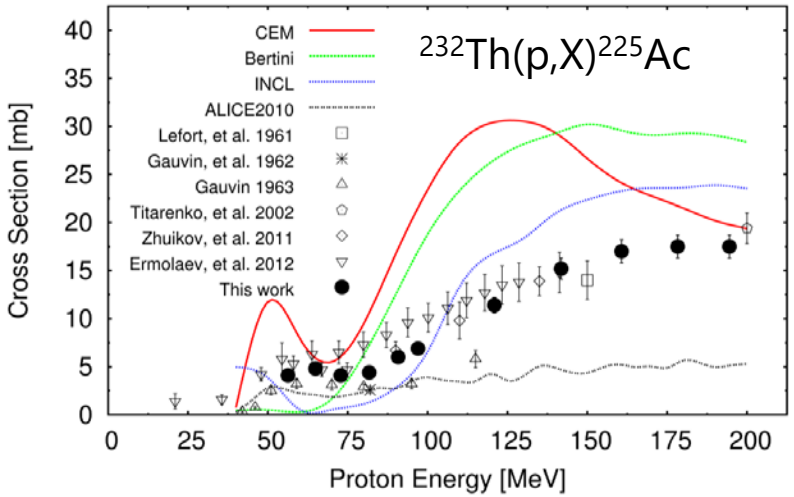


Proton Energy Distribution



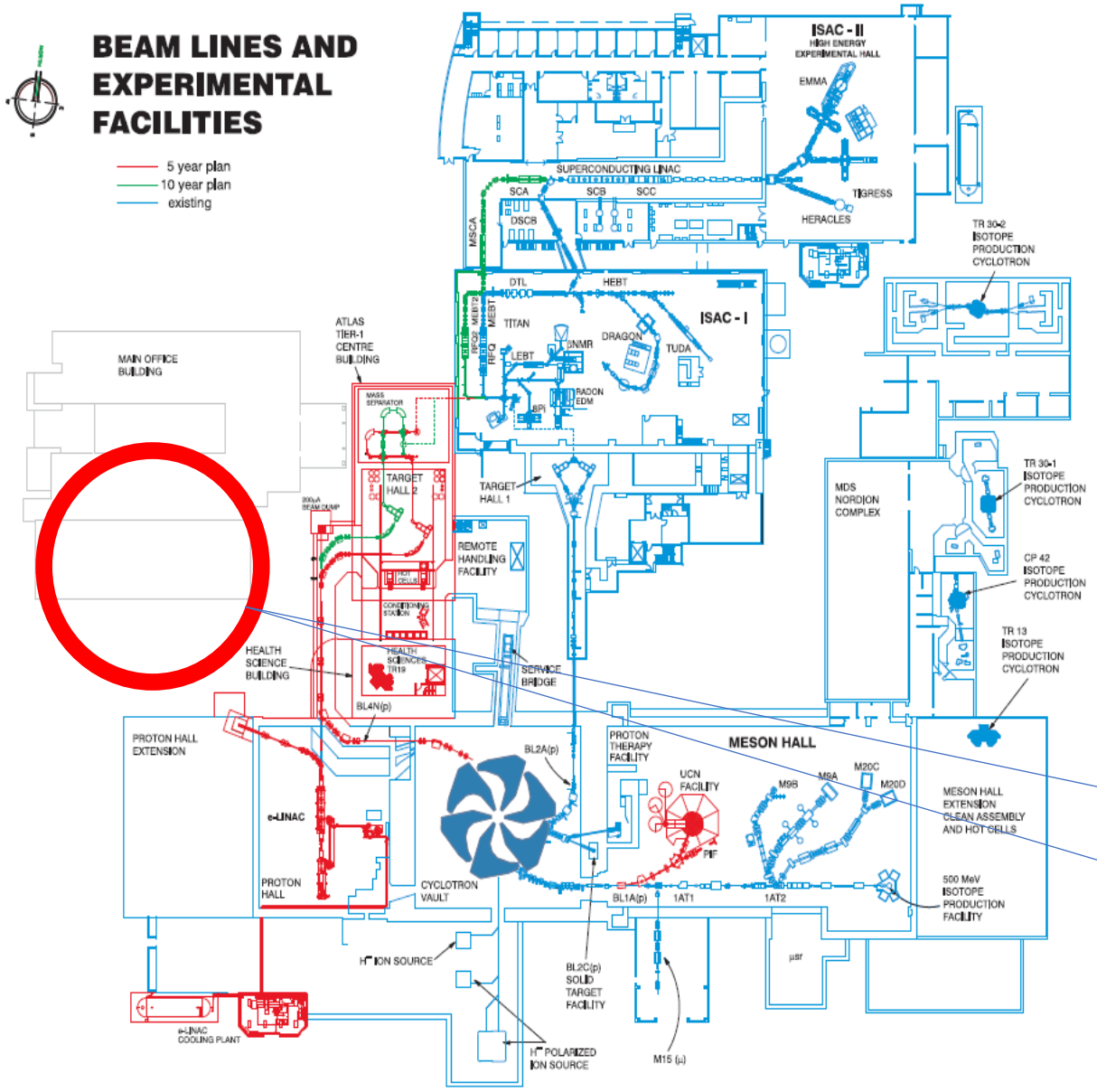
- Place symbiotic medical target in-between ISOL target and beam dump
- Pneumatic target delivery system from ARIEL hot cell complex to proton target station
- Independent operation from ISOL target
- development for in-cell processes and irradiation station required





J.W. Weidner et al., Applied Radiation and Isotopes 70 (2012) 2602–2607

Production of medical radionuclides at TRIUMF



TR-13

ISAC

Isotope Production Facility (IPF), BL1A

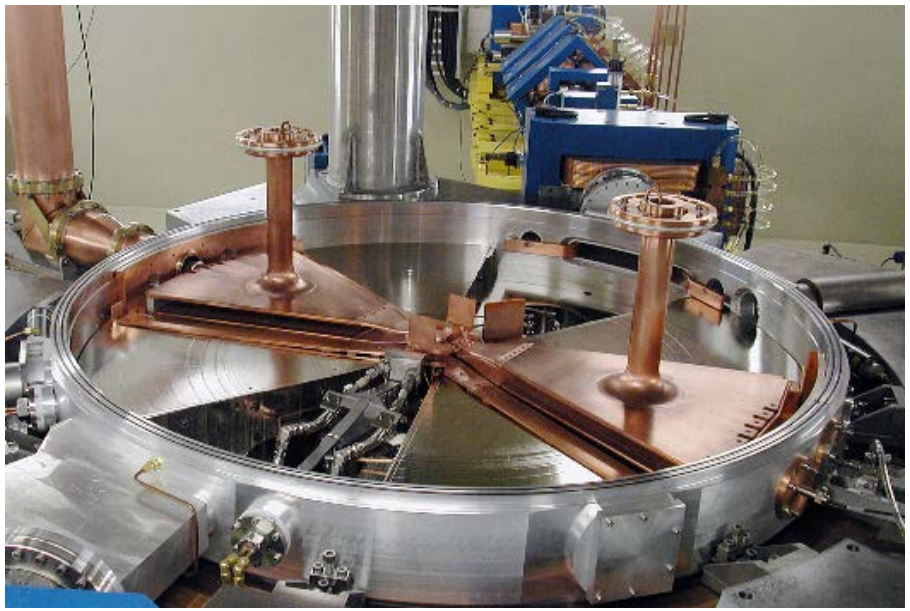
ARIEL
Collection chamber
Proton and electron beamlines

IAMI
TR-24
GMP facility

Institute for Advanced Medical Isotopes (IAMI)

IAMI will unite interdisciplinary partners to create a world-class center for advanced isotope research, development, and production for the life sciences.

TR-24: Proton Energy 24 MeV, 500 µA
will enable (p,2n) along with (p, n) reactions



IAMI Founding Partners

TRIUMF

BC Cancer Agency
CARE + RESEARCH

UBC

TRIUMF's "Hot Kitchen"

^{11}C PET

^{18}F PET

^{44}Sc PET/ ^{47}Sc β$^-$ therapy

^{45}Ti PET

^{52,54}Mn PET

^{55}Co PET

^{64}Cu PET/ ^{67}Cu β$^-$ therapy

^{68}Ga PET/ ^{67}Ga Auger therapy

^{86}Y PET/ ^{90}Y β$^-$ therapy

^{89}Zr PET

^{90}Nb PET

^{99m}Tc SPECT/ ^{94m}Tc PET

^{103m}Rh Auger therapy

^{111}In SPECT

^{119}Sb Auger/^{118}Sb PET/^{117}Sb SPECT

^{124}I PET/ ^{125}I Auger therapy

^{149}Tb Alpha therapy/ ^{161}Tb β$^-$ therapy

^{165}Er Auger therapy

^{177}Lu β$^-$ therapy

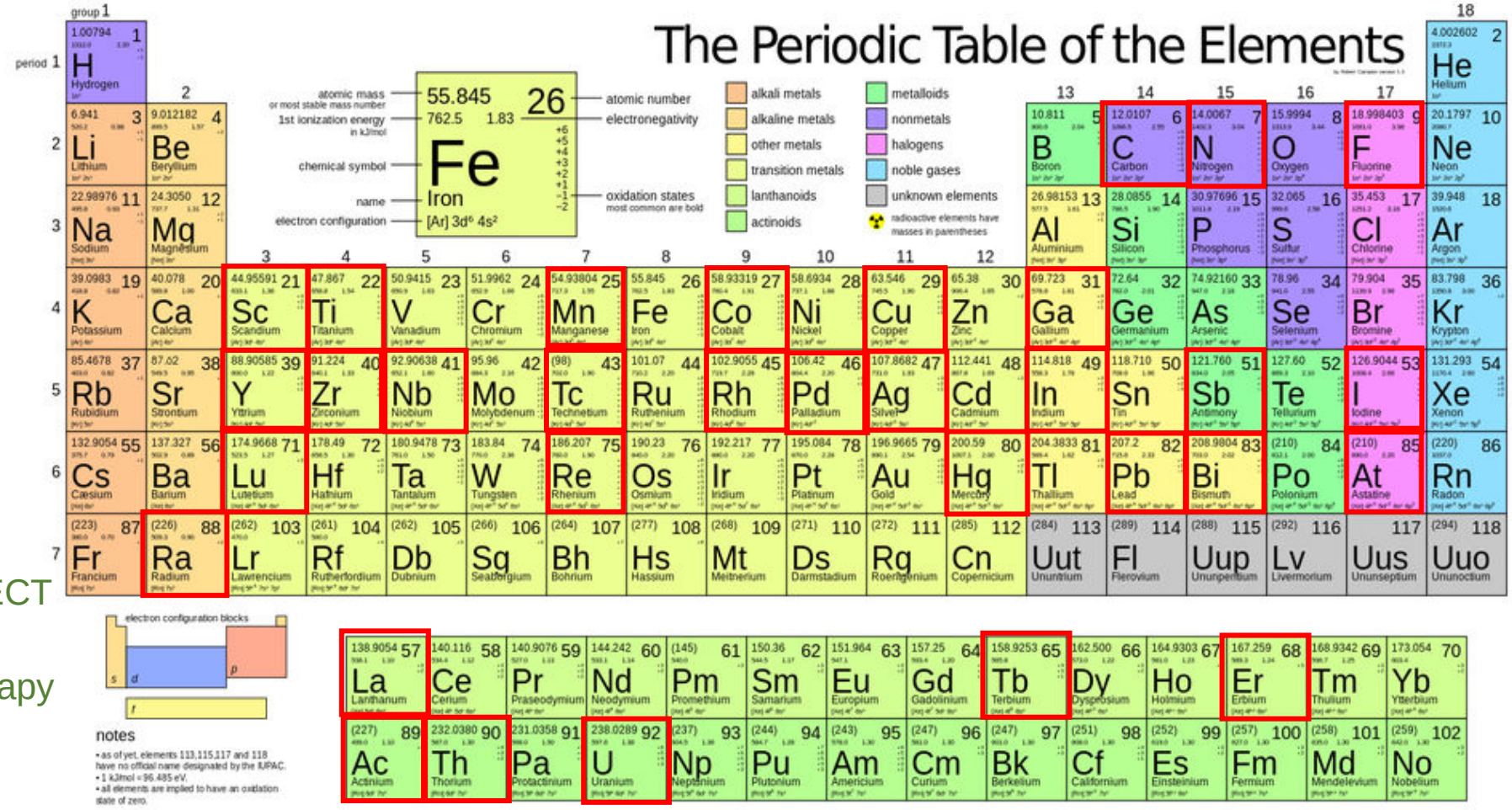
^{203}Pb/ ^{212}Pb Alpha therapy

^{213}Bi Alpha therapy

^{223,224}Ra Alpha therapy

^{225}Ac Alpha therapy

^{227,228}Th Alpha therapy



Blue available

Green can/planning be produced

Yellow commercially available

ISAC and Th spallation provides endless possibility for production of ~~many~~ other medical isotopes

Summary

TR-13

- Supporting clinical collaborations with radiohalogens (^{18}F and ^{11}C)
- Production of emerging radiometals for PET
- Production of promising therapeutic radionuclides for Auger therapy

ISAC

- Production of pre-clinical quantities of many novel/promising imaging and therapeutic radionuclides

IPF (BL1A)

- Large scale (clinical relevant) production of emerging therapeutic radionuclides (^{225}Ac)

ARIEL

- Proton beamline for pre-clinical and clinical supply of therapeutic radionuclides
- Possibility for electron beamline, utilization of (γ, n) (γ, p) reactions for production of medical radionuclides

IAMI

- Clinical level supply of medical radionuclides (^{18}F, ^{99m}Tc, ^{89}Zr, ^{64}Cu….) and GMP formulation of radiopharmaceuticals
- Provide more flexibility (e.g. enable p, 2n)

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Cyclotron group

Canadian Cancer Society / Société canadienne du cancer

CIHR IRSC
Canadian Institutes of Health Research / Instituts de recherche en santé du Canada

NSERC CRSNG

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Merci

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